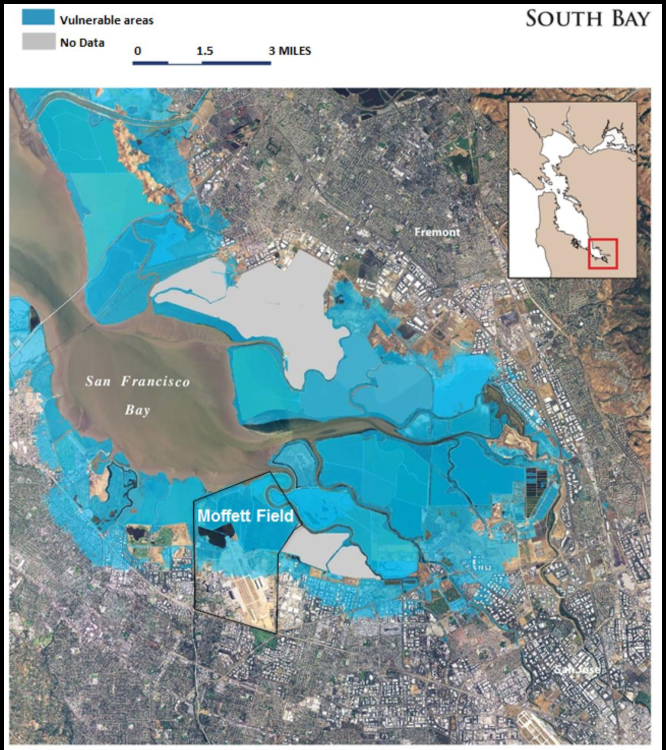
How Will Global Climate Change Manifest Itself at Regional and Local Scales?

M. Fellows, 2011



BCDC, 2011; Knowles, 2008; Siegel and Bachand 2002

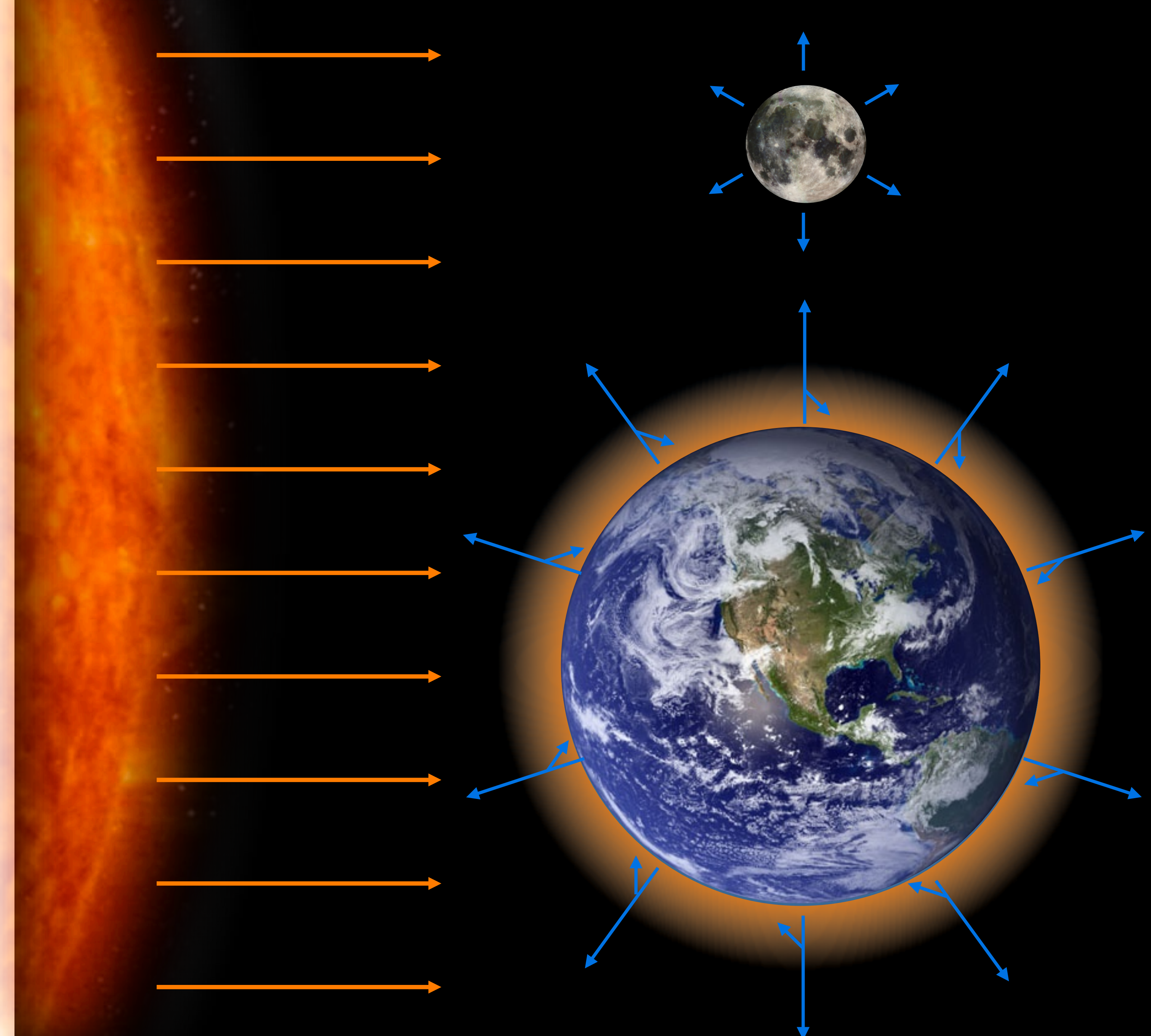
Radley Horton[1], Cynthia Rosenzweig, Dan Bader, Max Lowenstein, Cristina Milesi, Laura Iraci, and Ed Sheffner

[1]Columbia University / NASA GISS

NASA Ames Climate Change Adaptation Symposium

Mountain View, CA, February 4, 2011

Climate Change - Radiative Basis



Moon (no atmosphere)

Energy in = Energy Out

Earth

No Atmosphere

Energy in = Energy Out

Add Atmosphere

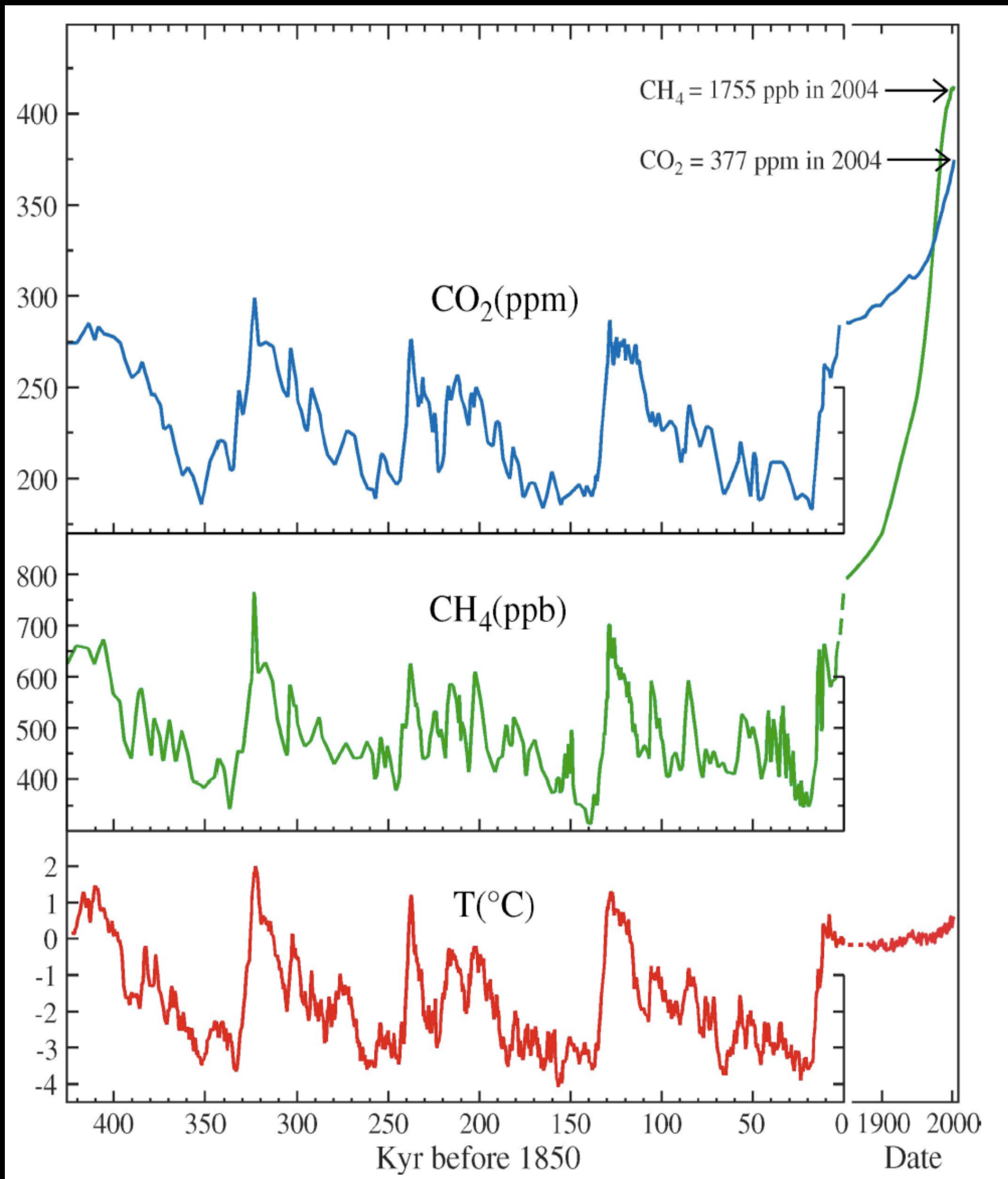
- Same amount of sunlight in

-Some of outgoing energy trapped (imbalance)

Warmer World

- Surface must warm to get back in balance

Climate Change – Paleoclimate Context

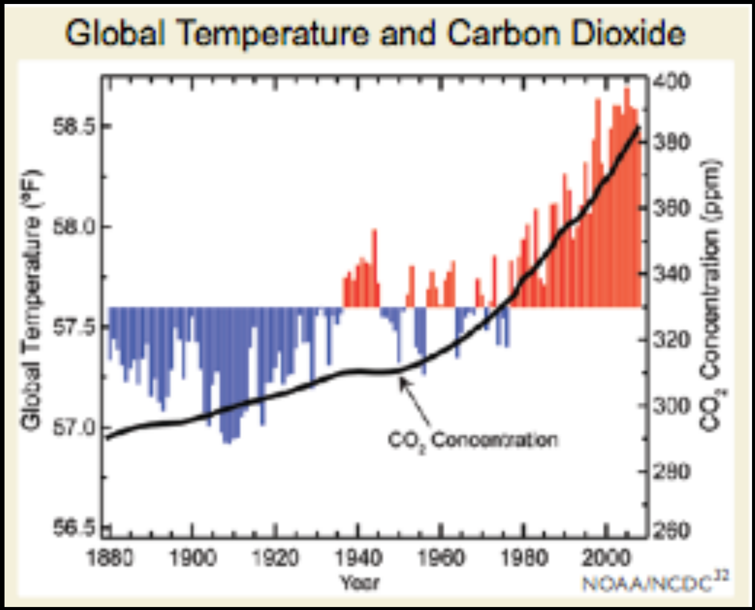


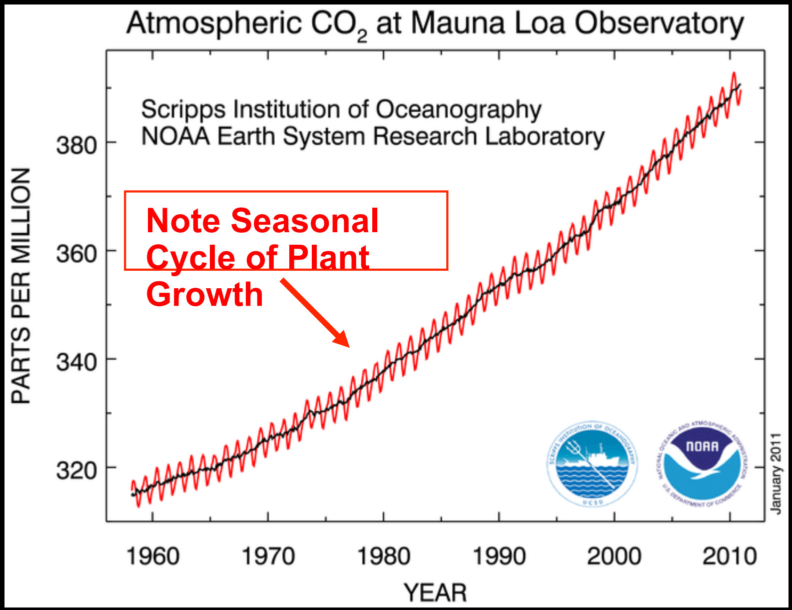
- Ancient climate states from "proxies"
  - Tree rings
  - Bubbles in ice cores
  - Fossil deposits
  - Sediment cores for lakes/ oceans
- Greenhouse gases and temperature track each other through history
  Clear relationship between temperature and GHG concentrations
- Present day levels and rates of change suggest the potential for future warming
  Current concentrations and rates of change exceed what has been seen in the past

Hansen, 2005

Greenhouse Gas Increases

- **Greenhouse Gases**
  - Transparent to sunlight, but trap thermal radiation
  - Long residence times
- **Recent Measurements**
  - Mauna Loa, Hawaii

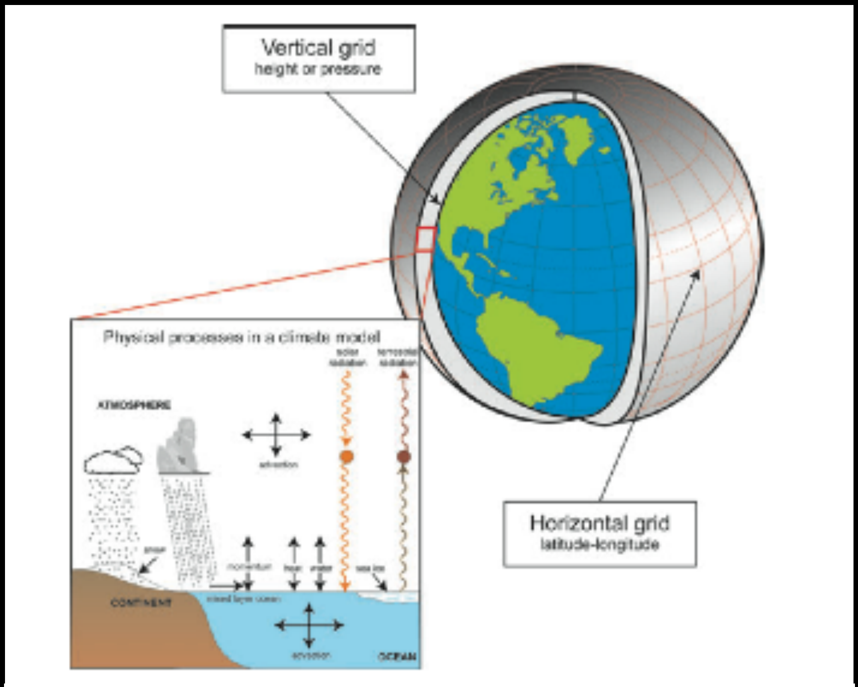


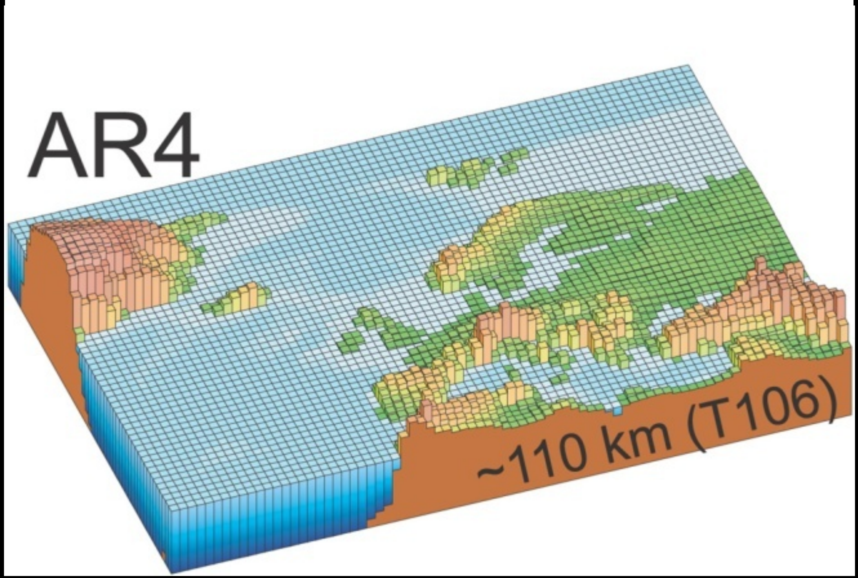


Source: NOAA

Climate Models

- Are physics-based, and solve equations for mass, momentum, and energy within ‘gridboxes’
- Include parameterizations of hydrology, clouds, vegetation, and ocean
- Couple fluxes between the atmosphere, ocean, land, and cryosphere
- Contain hundreds to thousands of pages of computer code, divided into interacting components
  - Dynamics
  - Radiation
  - Clouds
  - Etc.
- These calculations require the use of supercomputers and or parallel computing
- As computing power increases, model resolution (in time and space), complexity, and interactivity are all being improved





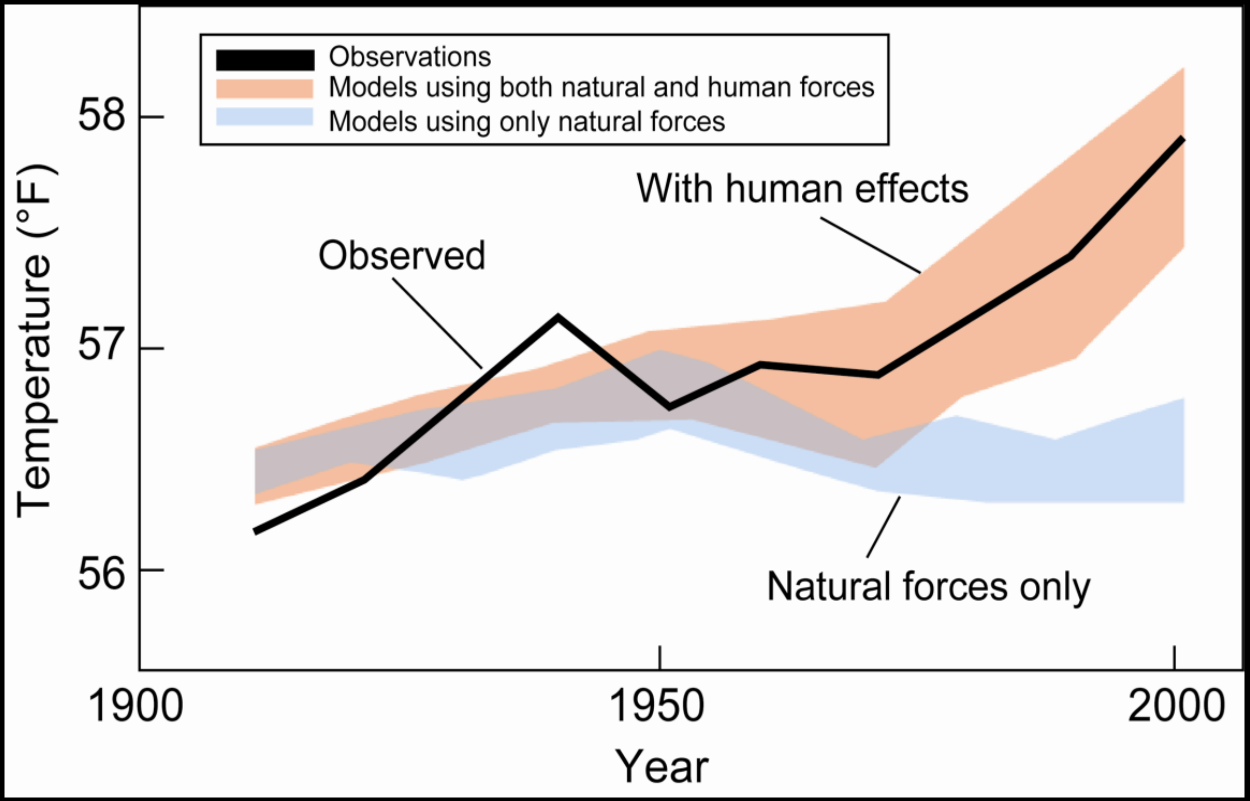
But advances tend to be gradual and MANY challenges remain

Adapted from IPCC, 2007

Human and Natural Factors

Need both natural and man-made influences (as well as feedbacks) to accurately represent historical climate

- **Natural:**
  - **Volcanoes**
  - **Sun spot cycles**
- **Man-made:**
  - **Greenhouse gas emissions**
  - **Aerosol emissions**
  - **Land-use changes**



IPCC, 2007

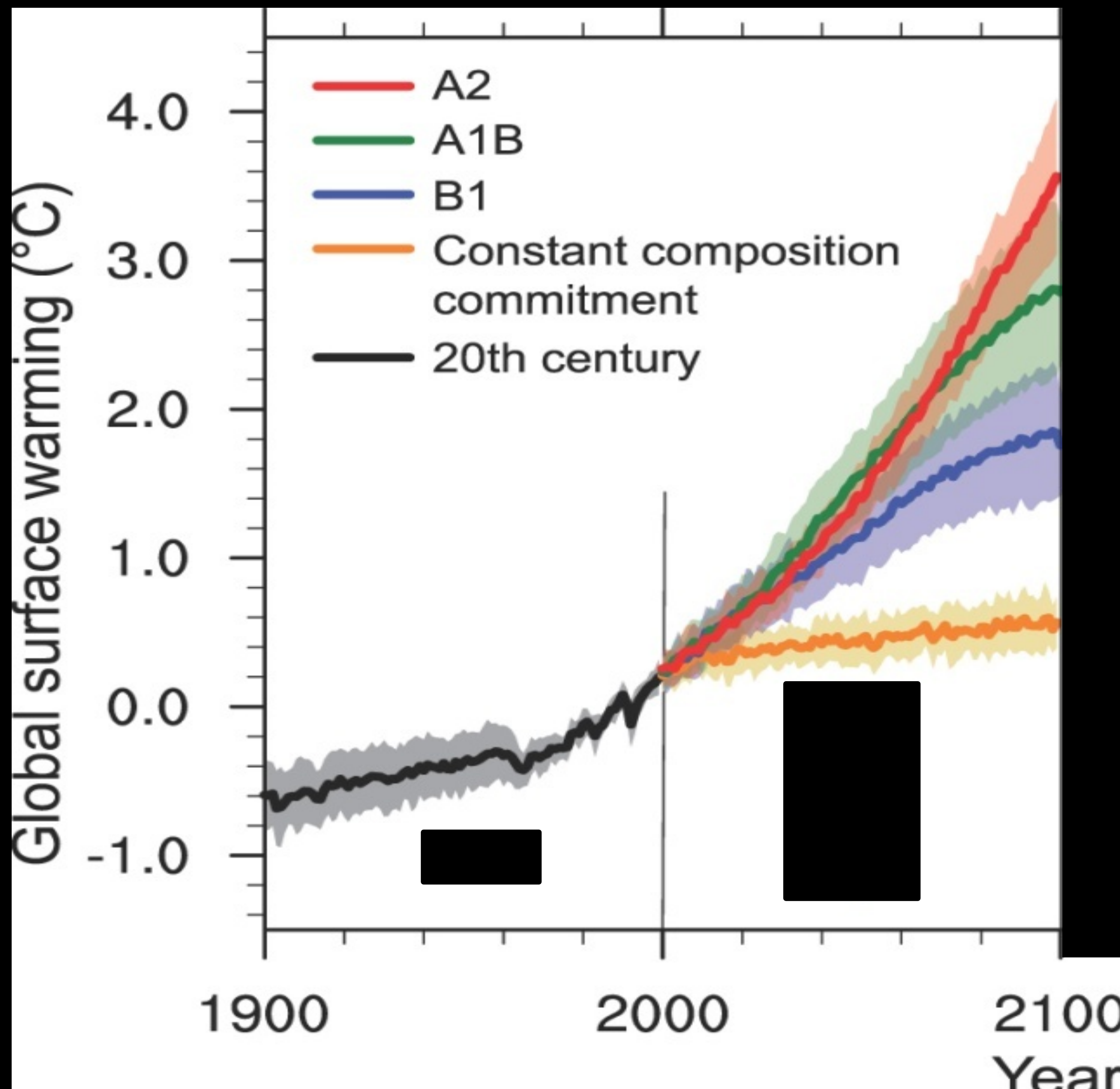
Future Projections

- **Use calibrated models to make "projections" of the future**

  -With greenhouse gas emissions

- **Emissions scenarios of the future depend upon**
  - Energy technologies
  - Economic growth
  - Population

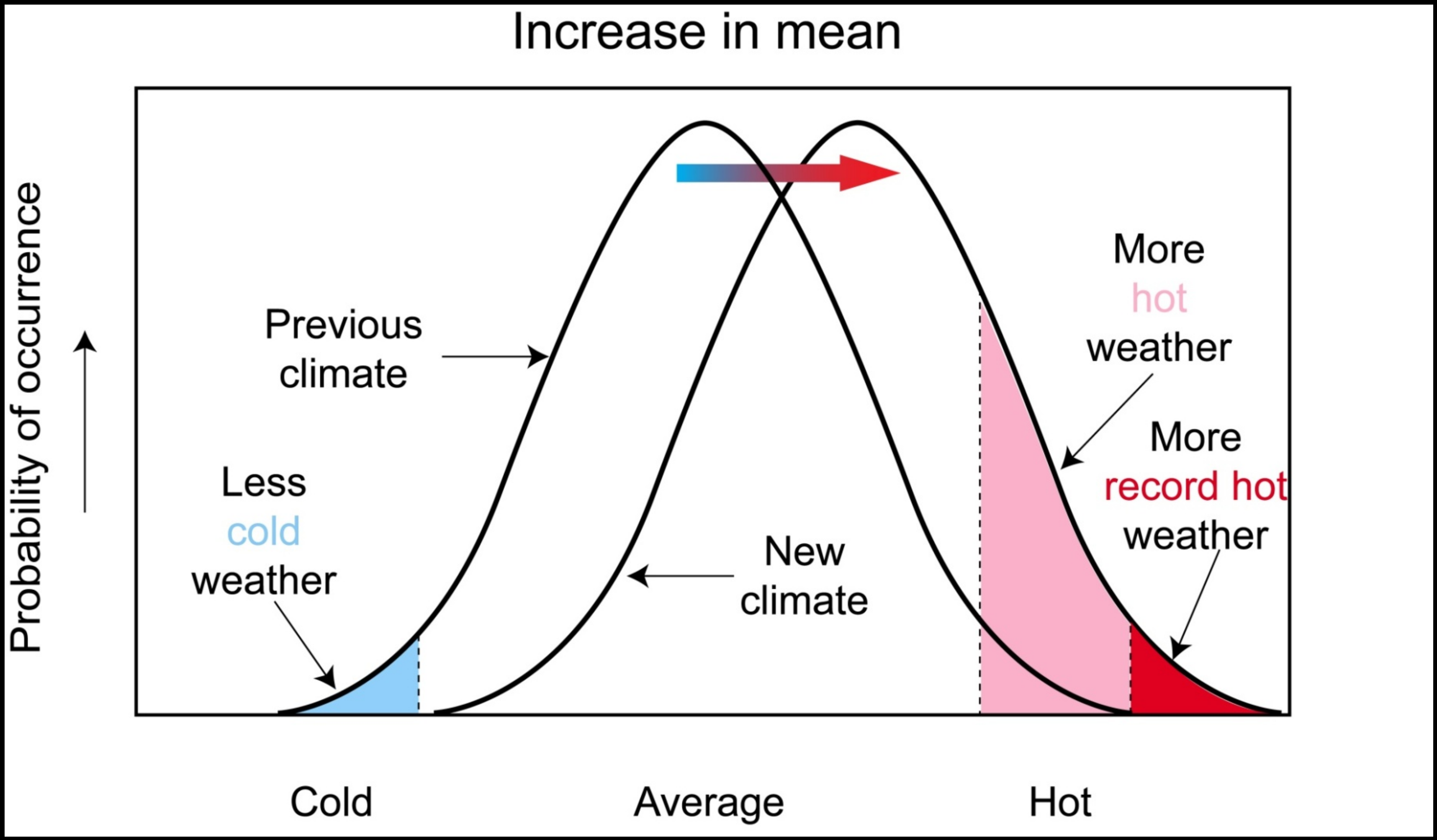
- **If we stop all greenhouse gas emissions now we still get warming**



The future depends on the steps we take now

IPCC, 2007

Potential Changes – Climate Extremes



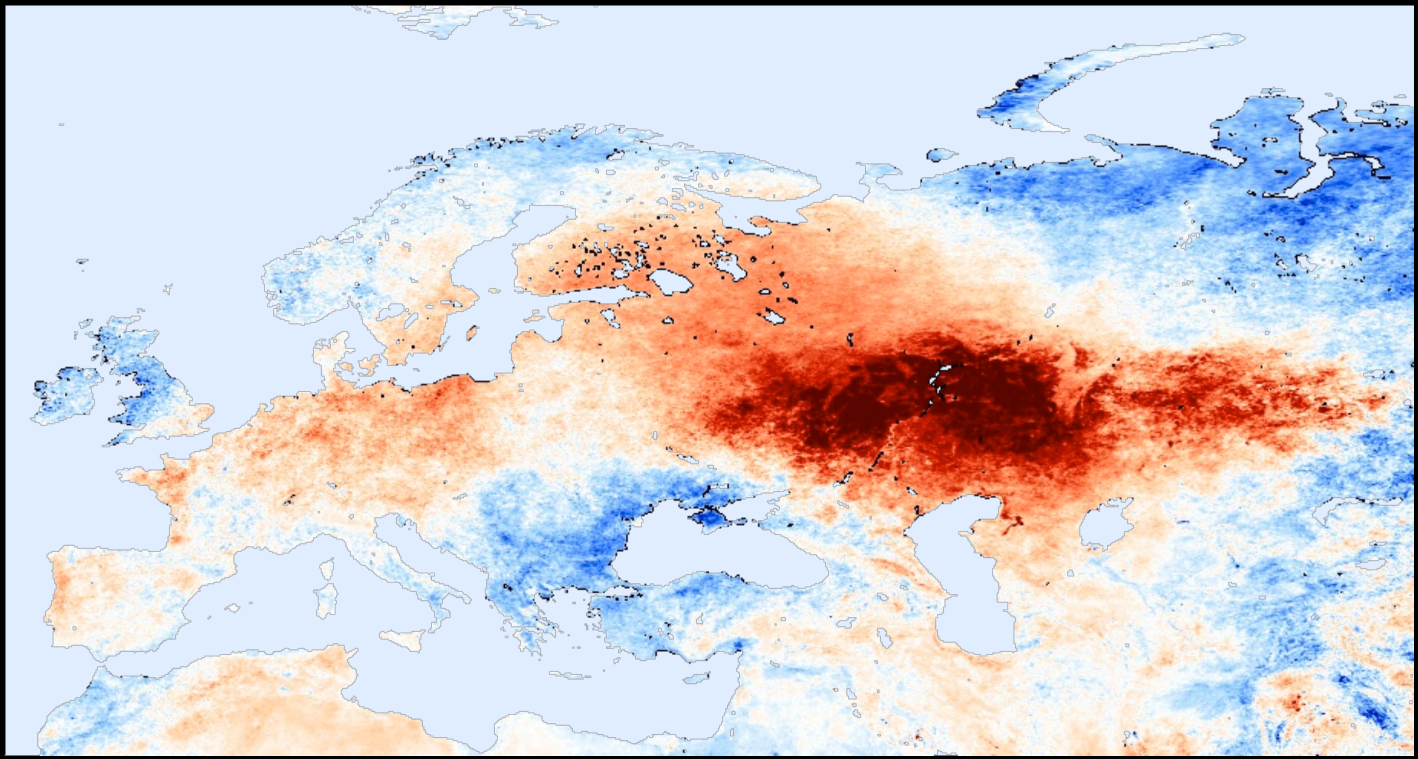
IPCC, 2007

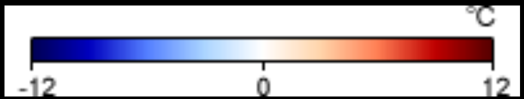
- **Natural variability will continue**
- **Small shifts in mean values can lead to large changes in the frequency of extremes**

Potential Changes – Climate Extremes

Largest impacts when natural variability combines with gradual mean changes

July 2010 Surface Temperature Anomaly





Heat wave in Russia caused crop failures and forest fires

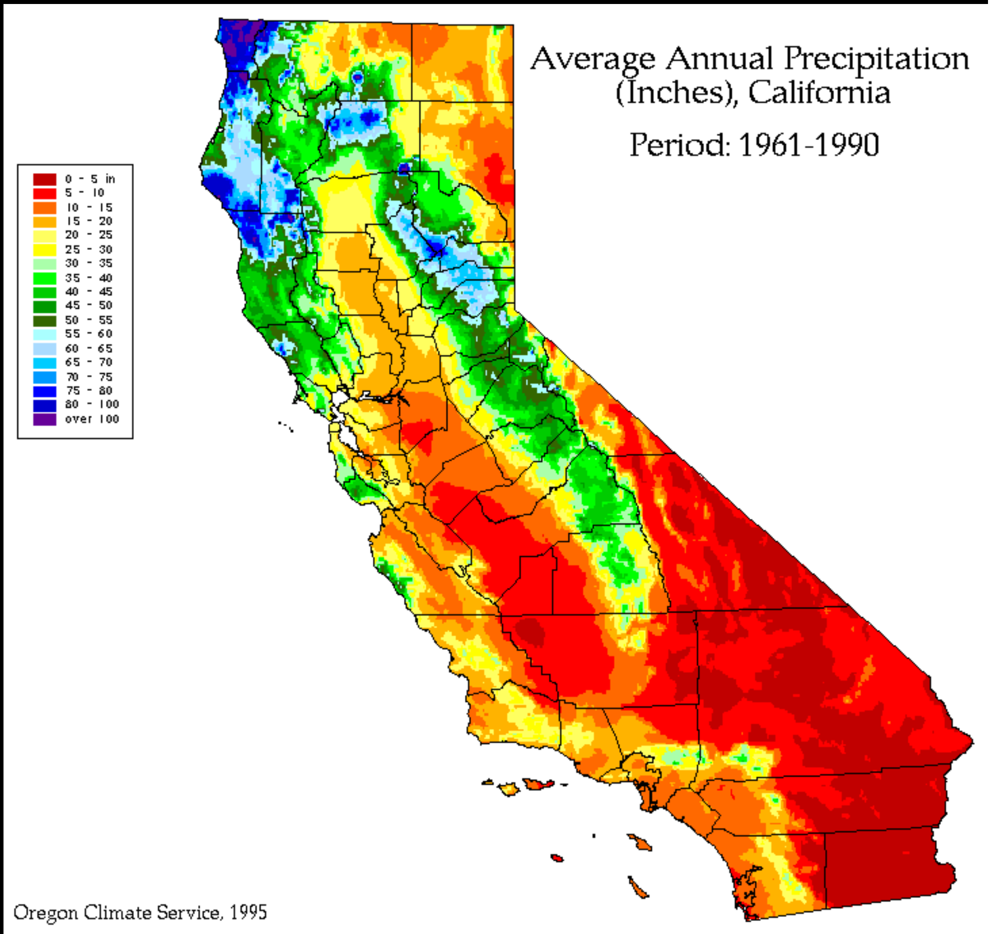
Source: NASA

California Assessment Context

- State Adaptation Reports
  - E.g., 2009 California Climate Adaptation Strategy
- Regional and Sectoral Efforts
  - E.g., San Francisco Bay Conservation and Development Commission Reports (BCDC), San Francisco Public Utilities Commission (SFPUC)
- City Initiatives
  - E.g., Mountain View, Palo Alto, Sunnyvale

Bay Area Regional Climate

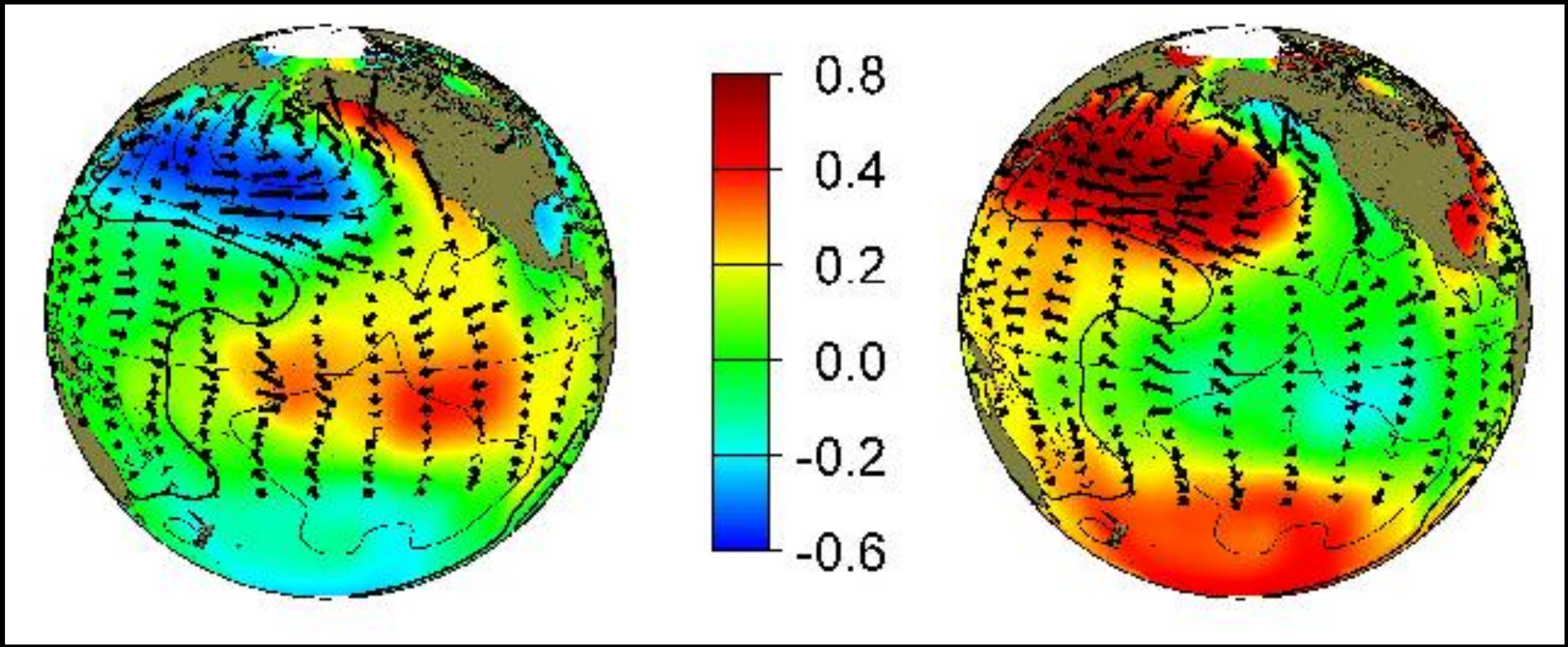
- Temperature
  - Range from an average of 49°F to 69°F
- Precipitation
  - Annual average of 15.5 inches
  - Primarily during cool season
- Local climate features
  - Coastal fogs
  - Land/ocean breezes
  - Sierra Mountain snowfall



Source: http://www.wrcc.dri.edu/precip.html

Pacific Decadal Oscillation (PDO)

Warm phase



Cold phase

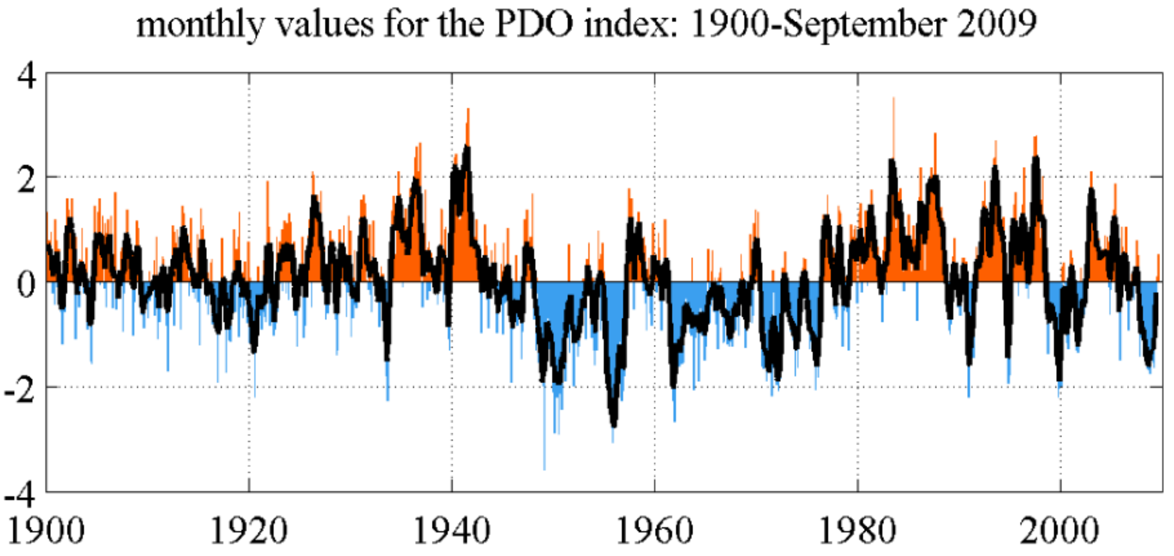


Figure source: University of Washington Climate Impacts Group, Nate Mantua (http://jisao.washington.edu/pdo/graphics.html)

The warm phase of the PDO is associated with higher than normal temperatures and sea levels in the Bay Area

The PDO also impacts Pacific fisheries and drought risk over much of the U.S.

Downscaling

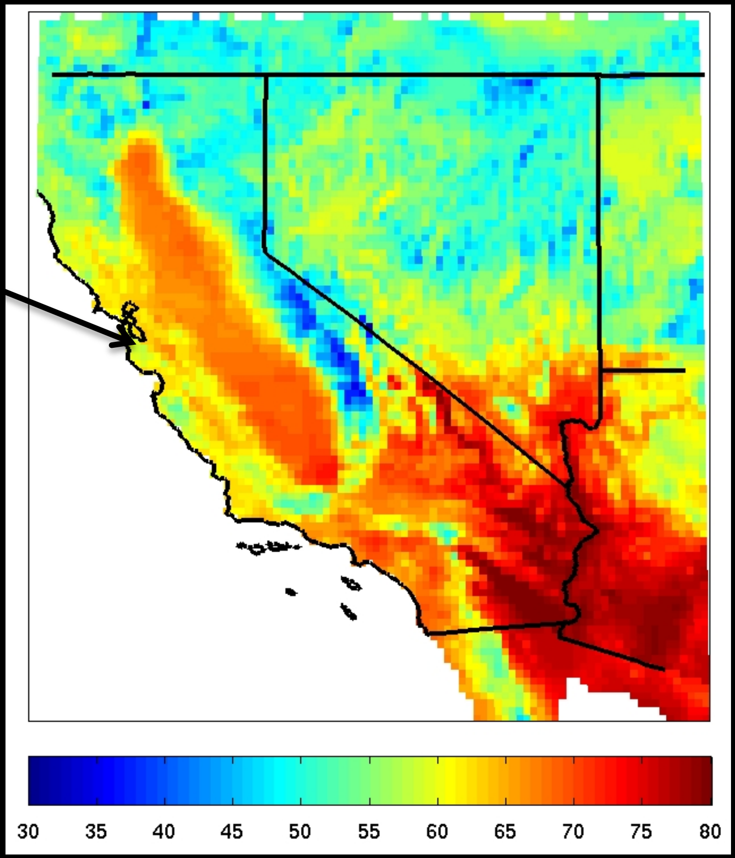
- Statistical downscaling produces finer scale features than Global Climate Models (GCMs) using historical relationships between the large and small spatial scales

- Dynamical downscaling achieved by running a GCM at high resolution over a small spatial domain

ARC

Regional Temperature Projections

16 GCM A1B Annual Temperature
2070 – 2099 (°F)



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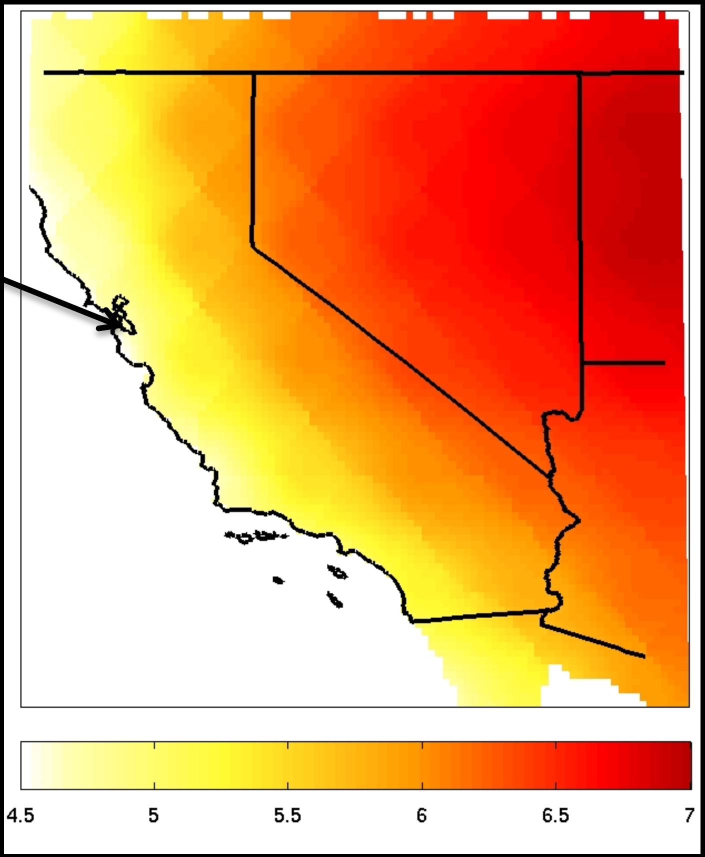
A1B 2080s 16 GCM Annual
Temperature Change (°F), relative to
1970-1999



NASA
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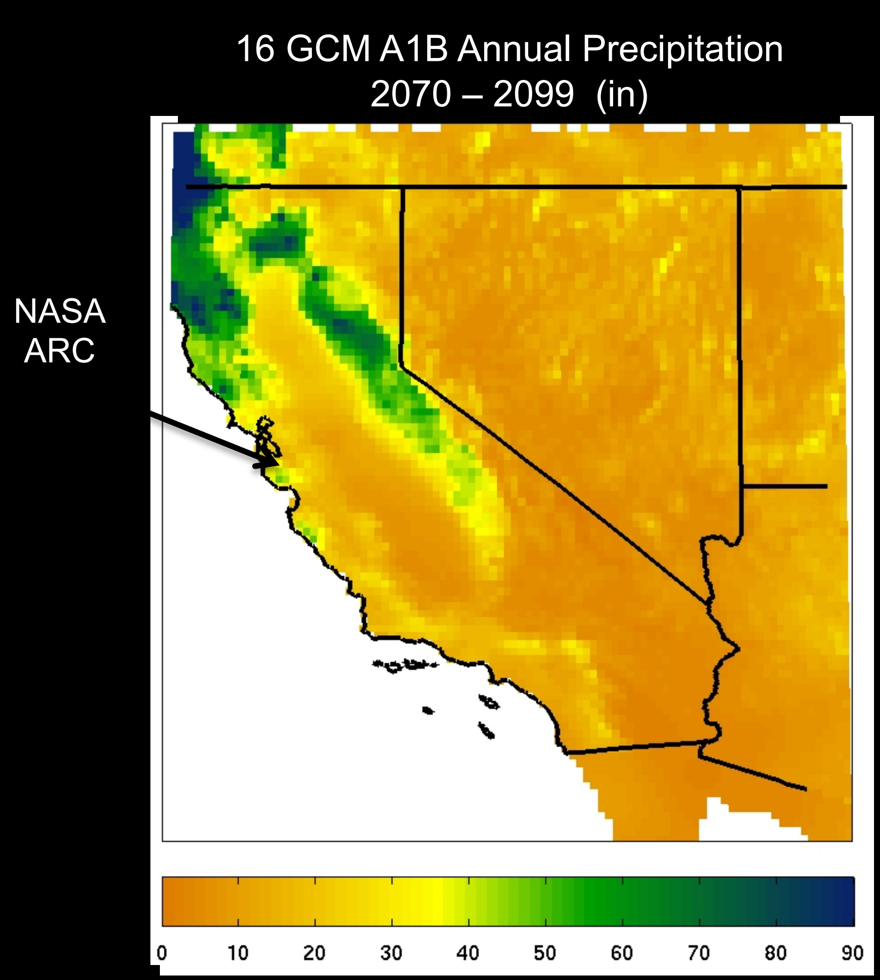
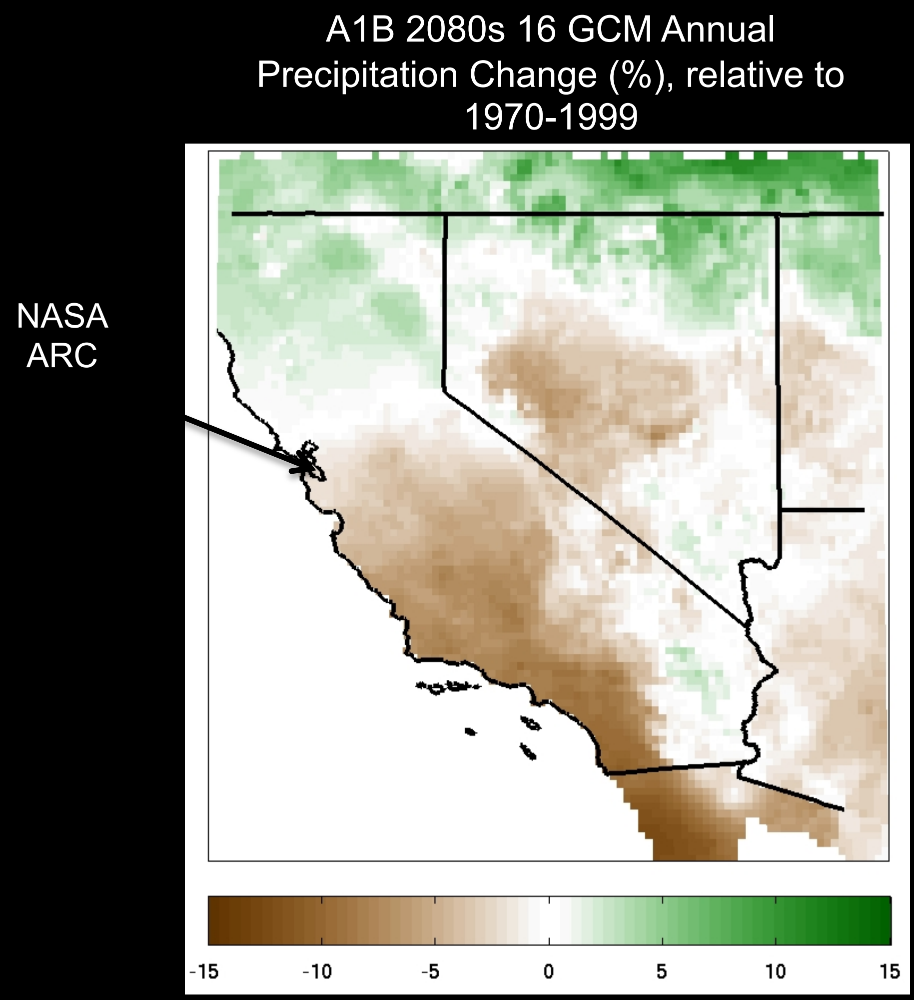
NASA GISS, based on WCRP CMIP 3 Bias Corrected Spatially Downscaled Projections (Maurer et al. 2007)

Regional Precipitation Projections





NASA GISS, based on WCRP CMIP 3 Bias Corrected Spatially Downscaled Projections (Maurer et al. 2007)

Extreme Event Projections

Daily Temperatures	Location	Baseline	2020s	2050s	2080s
Max temperature at or above 90 ˚F (days/ year)	Livermore	59	63 to 72	71 to 86	78 to 104
	Moffett Field	9	10 to 13	13 to 18	18 to 29
Min temperature at or below 40 ˚F (days/ year)	Livermore	94	70 to 80	55 to 70	37 to 63
	Moffett Field	32	18 to 24	10 to 19	5 to 14

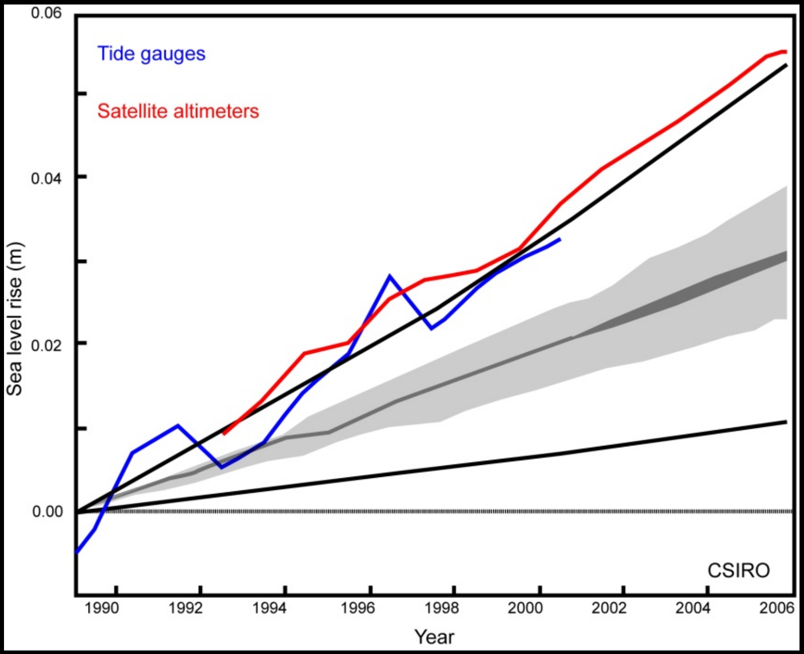
The number of days per year exceeding 90 °F is projected to rise in the coming century, and the number of days with temperatures below 40 °F is projected to decrease.

NASA GISS, based on WCRP CMIP 3 Bias Corrected Spatially Downscaled Projections (Maurer et al. 2007)

Sea Level Rise

- Observed sea level slightly above high end IPCC projections
- Low spatial resolution and incomplete physics prevent climate models from fully capturing processes such as:

1) Melt water ponds and basal lubrication of glaciers
2) Thinning of buttressing ice shelves that hold back land-based ice
3) Thinning of ice at grounding lines



Potential Impacts

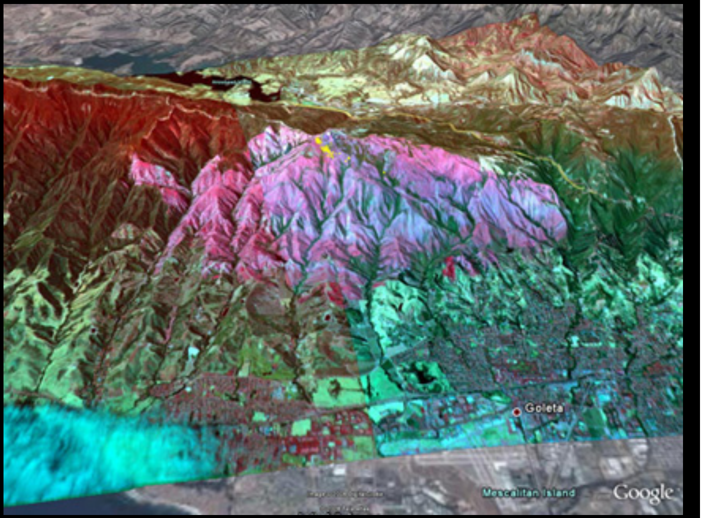
- Increased temperature
  - Changing energy costs
  - Stress to building materials and system
  - Implications for the safety of workers and the surrounding community

- Sea level rise
  - Partial inundation of Center
  - Flooding of transportation corridors
  - Reduced emergency response capabilities
  - Salination of water supply and freshwater ecosystems

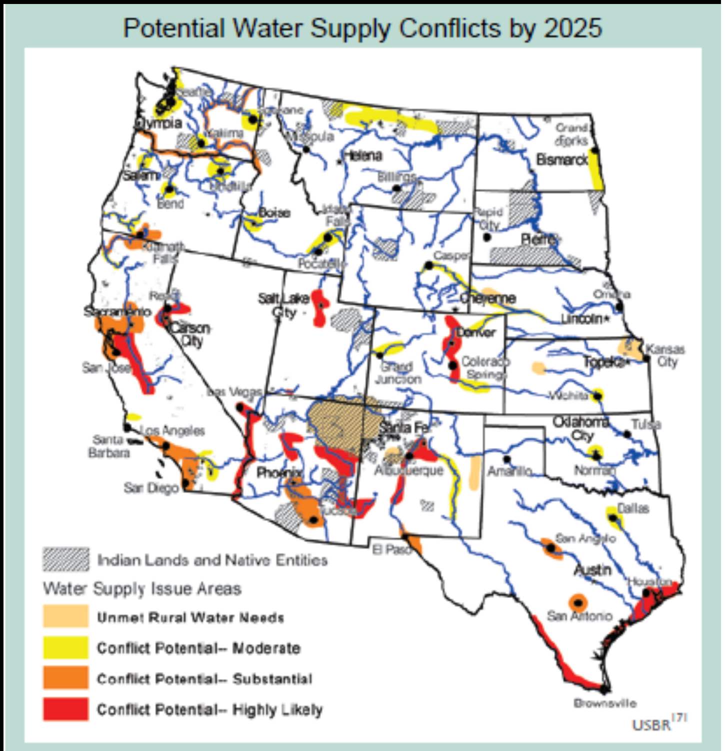
BCDC, 2011; Knowles, 2008; Siegel and Bachand 2002

Potential Impacts

- Coastal flooding
  - Transport of pollutants
  - Erosion
  - Impacts to wastewater treatment plants



- Precipitation changes
  - Reduced reliability of late season fresh water from diminishing snowpack
  - Seasonal reductions in water flow for hydroelectric power
  - Seasonal increase in fire risk
  - Increased winter and spring flood risk



Conclusions

- Human activities are expected to be the driving factor behind 21st century climate changes
- In the San Francisco Bay Area, rising temperatures and sea levels are expected
- Remote climate changes and may have large impacts locally
- Regionally and sectorally coordinated adaptation activities can reduce negative outcomes and leverage opportunities